Renewable and Sustainable Energy Reviews 29 (2014) 828–834

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The present and future of smart power grid in developing countries

M. Fadaeenejad [a,*], A.M. Saberian [a,*], Mohd. Fadaee [b], M.A.M. Radzi [a], H. Hizam [a], M.Z.A. AbKadir [a]

[a] Department of Electrical and Electronic Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Malaysia
[b] Department of Electrical Engineering, Islamic Azad University (IAU), Mashhad Branch, Iran

ARTICLE INFO

Article history:
Received 15 October 2012
Received in revised form
19 August 2013
Accepted 24 August 2013
Available online 2 October 2013

Keywords:
Smart grid
Developing countries
Renewable energy
Power grid

ABSTRACT

Strong and huge interests on smart grid have increased extensively in recent years around the world. This scenario could be a promising reason for future research in this area. This next form of electricity grid will be able to manage various parts of power production from power plants to the customers. Smart grid has become a major challenge in developed nations in both research and utilization aspects. On the other side, application of smart grid in developing countries is still lagging behind as compared to the developed ones. However, most of developing nations are currently investigating potentials of some pilot projects or few research works. In this article, the applied activities in developing countries for smart grid are reviewed and categorized into two major groups: group of pioneer developing countries in smart grid and other developing countries are placed in another group. The findings demonstrate that a few countries such as China, India and Brazil have had proper planning and development in this technology. In some cases like China, the efforts are considered comparable with developed nations like U.S. Therefore, according to the development progress for smart grid in China, India and Brazil, a pattern of reference for other developing countries is suggested.

Contents

1. Introduction

Smart grid is considered as a future of power grid which is able to manage the production, transmission and distribution of electricity by modern technology [1–5] to resolve many issues of current power grid systems. Some of these obstacles such as voltage sags, blackouts, overloads and old grids are part of economical issue and other factors especially carbon emissions which contribute to the environmental problem [6,7]. Thus, considering both economical and environmental interests, application of smart grid will be essential for near future [8–14]. Modernization of power grid by new facilities has been a reason for rapidly emerging of smart grid in many regions around the world [9,15] especially in developed countries [16,17]. Moreover, smart grid is necessary for developing countries in future due to integration with renewable energies and energy management features [18–20]. However, there are many challenging aspects

Abbreviations: RE, Renewable energy; IEA, International energy agency; GDP, Gross domestic product; AMI, Advanced metering infrastructure; WAM, Wide area measurement; HEM, Home energy management; DA, Distribution automation

* Corresponding authors. Tel.: +60 172797162/+60 172493230.
E-mail addresses: Mfadaee@gmail.com (M. Fadaeenejad), Saberian.res@gmail.com (A.M. Saberian).

1364-0321/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.rser.2013.08.072

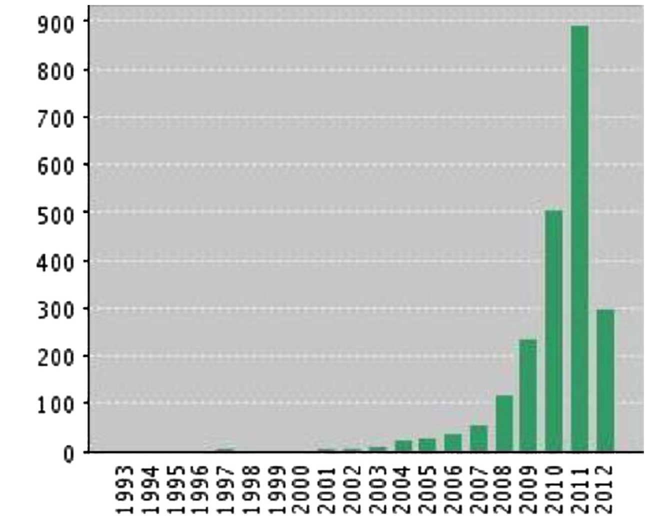


Fig. 1. Published items about smart grid in recent 20 years.

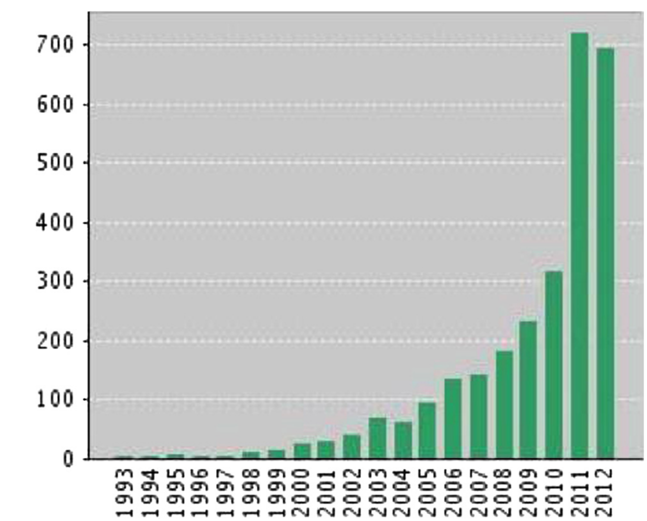


Fig. 2. Citation items about smart grid in recent 20 years.

for this technology to expand due to its broad nature and multi disciplinary aspects, that can make it becomes complicated and difficult to be implemented by governments in such countries [21].

Taking into account information from the ISI Web of Knowledge, Fig. 1 shows the published items about smart grid in a period of 20 years. As shown in Fig. 1, the items about this topic have just been published from 2001. Thus, it is observed that smart grid is extensively new topic. Moreover, before 2008 there were less than 50 papers and only after 2008 this research area has become a hot topic.

Obviously, in 2011 there was a rapid increase in number of publications and citations (Fig. 2). Furthermore, although in 2012 the published works were about 1/3 of 2011, however, the citation number, as shown in Fig. 2, is equal in 2011 and 2012. Therefore, the promising future of smart grid will be guaranteed.

On the other hand, although development of smart grid in developed countries is greater than developing ones, but for developing world there are some similar or different factors that clarify the urgency of application of smart grid as compared to the developed world [22]. The U.S. and the E.U initiated smart grid technology and number of power grid practices towards smart grid since 2003. As an example, there is a project in Europe since 2004 named “smart grid project report” about research and construction of smart grid to help E.U power grid to be more flexible, economical and reliable by 2020 [23]. Furthermore, a recent study discussed about the customer engagement in such projects in Europe [24]. On the other side, the application of smart grid in a few developing countries just started from 2006 [25].

This paper provides an overview of the research works about the smart grid in recent years and reviews the government's plan for application of smart grid in developing countries. The results should be able to help researchers and decision makers for utilization of future modern grids in such countries.

2. Smart grid in developing countries

In general terms, environmental emissions and energy efficiency are two main benefits of smart grid [26]. Environmental impacts and energy efficiency are managed in production, transmission and consumption of power grid. Moreover, the stability, security and economical improvements are further advantages [27].

The next architecture of power grid will be changed due to usage of various sources of energy such as renewable ones and two-way power and data flow as shown in Fig. 3 [28].

Fig. 3 shows one the accepted models of smart grid. There is much more architecture that has been proposed for such grids [29–31] with proper security protection [32]. The reliable operation and protection are assumed vital for smart grid due to the variety of energy sources and communication networks [33].

Some requirements are needed for utilization of smart grid in future [34]. One of these requirements is upgrading infrastructure such as using smart meters with a proper investment [35]. Smart meter is a primary device and infrastructure for smart grid utilization and is defined as an advanced energy meter. Smart meters are able to make a conventional grid more flexible for application of many techniques and software [36]. Furthermore, smart meters are key devices for energy management purposes [37].

Nowadays smart grid is become essential for developed countries and these nations have done much of the investigation in this issue. A research by Center for Study of Science Technology and Policy (CSTEP) in India presented five main factors to make power grid in developing countries smarter. Some developing countries such as China, India and Brazil are forefront of these efforts [22]

- **Quality and reliability of power:** In some cases in developing countries the quality of grid connection is poor and consequently the electricity is available for certain times. Demand balancing and distribution automation are two features of smart grid that can keep power continuously. Therefore, the power flow can be managed in a smart grid system [38].
- **Build a smart grid instead of conventional one:** In some developing nations such as Tanzania the power grid is not fully built out. In Tanzania, 90 percent of people do not have access to the electricity through power grid. Such countries can start with smart grid instead of old model of grid.
- **Cost effective investment for rapid energy demand:** Increasing energy in some developing countries such as China needs a cost effective investment for smart grid. In these nations the addition of customers can help to return the investment.
- **Addition of renewable energy to smart grid:** Distribution generation by renewable energy sources can be added to the smart grid and managed properly [39,40]. Furthermore, the related problems due to intermittency of such energies can be solved [41–43].

Welsch in [44] categorized various elements for implementation of smart grid according to needs of developing countries. The authors explained that such elements can help to accelerate achieving smart grid. These factors are: (1) design of transmission and substation system: to reduce losses for long transmission

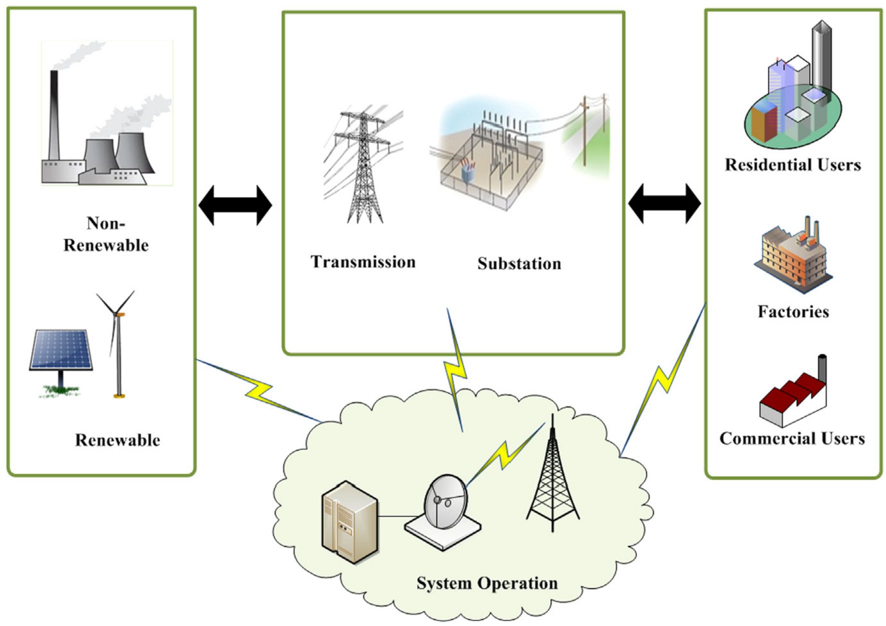


Fig. 3. Smart grid power system architecture.

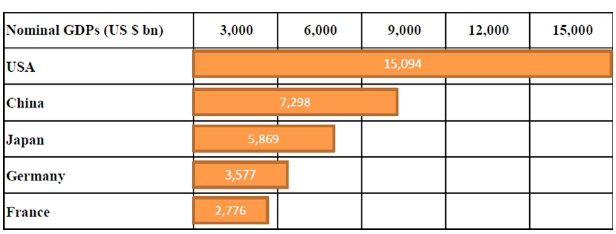


Fig. 4. Comparison of 2011 nominal GDPs of major economics in US$ billions according to IMF data.

lines; (2) design of distribution system: intelligent control by using smart sensors and flexible switches; (3) smart distributed generation: maintain power quality against fluctuating generation using smart components; (4) load side management: managing demand by load control switches to reduce load-shedding; (5) local charging stations: to supply electricity for basic needs of rural communities; (6) billing service: to implement billing service via mobile phone; (7) information system architecture: applying intelligent control by data management tools for two-way flow of information in smart grid; and (8) financing: utilization of smart grid requires high level of investment by government. The author listed many other elements such as operation and quality of supply, environment, technical complexity, human capacities, regulations and standards and modeling.

Although, the application of smart grid has not been defined in most of developing countries, but some of them such as China, India and Brazil have had a significant efforts in this field [22]. Whereas there are different strategies in such countries for future of grid, in this paper the strategies will be considered indifferent classifications as follows.

2.1. Smart grid in China

China is considered as one of the fast growing economics in developing nations. According to the International Monetary Fund (IMF), it has the second largest economy in the world with about US$ 7.298 trillion in 2002 (Fig. 4) [45].

Based on World Bank report [46], more than 1.5million people in developing countries are living without electricity and it seems that there is no change in future with the same trend [47]. Therefore, one of the main purposes of smart grid is to meet the electricity demands in future [1,12,48]. China has 233% growth of electricity demand from 2007 to 2050 [49] as shown in Table 1.

Table 1
Growth for world electricity demand from 2007 to 2050.

Region	2007 electricity demand (TWh)	2050 electricity demand (TWh)	Percent growth 2007–2050 (%)
World	16,999	36,948	117
OECD North America	4664	6252	34
OECD Europe	3136	4071	30
OECD Pacific	1681	2311	37
Economies in transition	1149	2348	104
China	2856	9500	233
India	567	3453	509
Other developing Asia	853	2822	231
Africa	521	1691	225
Latin America	808	2062	155
Middle East	594	2537	327

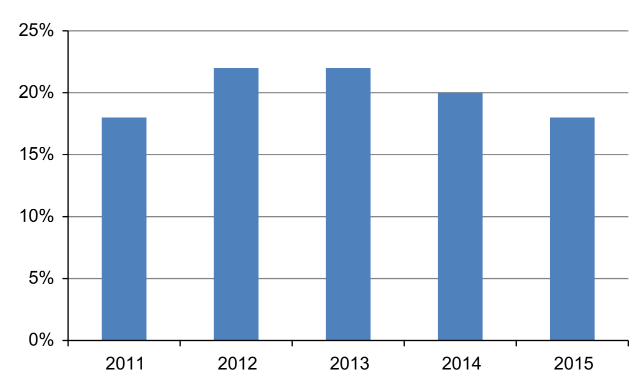


Fig. 5. China's smart grid investment ratio during "12 Five Year Plan" Period.

Table 2
China's smart grid investment from 2011 until 2015 in each sector.

Sections	2011	2012	2013	2014	2015
Generation	16.7	16.7	1.7	1.7	1.6
Transmission and transformation	123.8	160.9	159.5	158.7	161.9
Distribution	58.2	58.8	92.3	40.8	46.1
Utilization and dispatch	149.2	194.6	152.5	219.1	174.9
Communication	172.4	187	166.5	149.1	135.4

Since 2006 smart grid technology was introduced into China and relevant research works have been started. Soon after [50] a project named Solution Architecture for Energy (SAFT) was designed containing few parts of using sensors for connection of equipments to improve the digital level, data collection and system integration. In this project, operation is optimized and managed based on data analysis [25]. Furthermore, China will be one of the best markets of smart grid and State Grid Corp has a goal for implementation of smart grid by 2020 [22].

Through 12th five-year plan of China, a key government priority is further to develop of the country's power grid with the large-scale construction of a smart grid. State Grid's investments will reportedly exceed RMB 17 billion during this time [51]. There are many key changes such as social, environmental and economic solutions in smart grid plan in China [52]. Perhaps as another key important factor, China is also looking to the smart grid which may help creating 15 million new jobs, specifically to employ rising number of newly graduated workers [53]. China's smart grid investment ratio during 12th five-year plan period and for different smart grid sectors is shown in Fig. 5.

Development of smart grid in China in different sectors, and related changes in funds and their trends are clearly shown in Table 2 in detail [25].

In academic field, there are many articles about smart grid in China in recent few years. Some of them evaluate smart grid by energy aspects. Siming Li [54] explained the smart grid development in China. This paper discussed the development and challenges of the power grid. De-Qiang Sun in his work [27], stated about the utilization and development strategies of smart grid and new energy in China. He mentioned that smart grid and renewable energy integration is defined as the main solution for low-carbon economy of China. As a complementary, Xin-Wei in [55] reviewed the development of smart grid in China and analyzed the challenges against Chinese power enterprises.

The others discuss the construction and infrastructure of future grid in China. Authors in [54] presented a set of suggestions for construction of Chinese style smart grid. In [56] authors presented development in power and transmission infrastructure of China. Wu [57] analyzed construction of information system for smart grid of China. In [58], authors evaluated the investment system that is important for future of power grid in China. Sun [59] reviewed the assessment system of smart grid in China.

Smart grid of China is announced in May 2009 after US and Europe smart grid plan [60]. In a recent research work, US and China smart grid policy is comprised and it is defined that this policy is dependent to the state of power industry. The “supply-side policy” with a focus on “public enterprise, scientific and technical development and legal regulatory” policies are applied and preferred in China [61].

Therefore as a result in this part, China has been leader in smart grid among developing economics.

2.2. Smart grid in India

Smart grid investment in India has not been same as China. Some pilot projects are investigated by Indian utilities and Bangalore Electricity Supply Company (BESCOM) is working on such pilot projects [22].

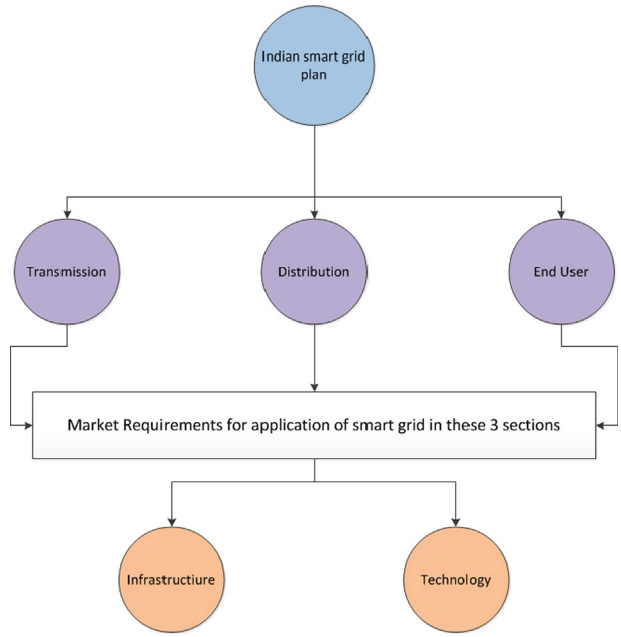


Fig. 6. Approaches for Indian smart grid.

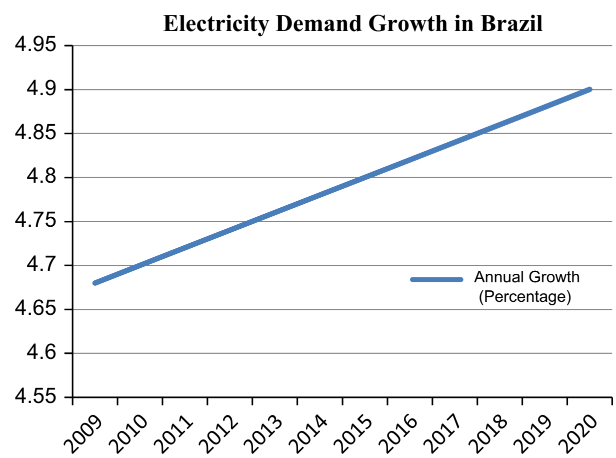


Fig. 7. Electricity demand growth in Brazil from 2009 to 2020.

On the other side, there are many additional reasons for necessity of smart grid in India. First, power theft that is a common problem in India due to little protection of grid and high poverty rate [22]. The second reason is the highest rate of growth for electricity demand as shown in Table 1 [62]. The transmission and distribution losses are the third one. The rate of such losses in India is about 26 percent of total production which is considered highest rate in the world [60]. Indian smart grid approach is shown in Fig. 6 [63].

Although power grid in India has been weak as compared to other countries, there are proper opportunities to build smart grid [60].

As an academic work, Sinha et al. [64] evaluated the smart grid initiatives in India. One of the elements in this paper is to elaborate the methodology of implementing the smart grid project in Indian power scenario. Acharje in [65] completed Arup's work by discussing some problems against implementation of smart grid in India. On the other side, Ganesh and Jadhav [66] considered some essential technical challenges for development of smart grid

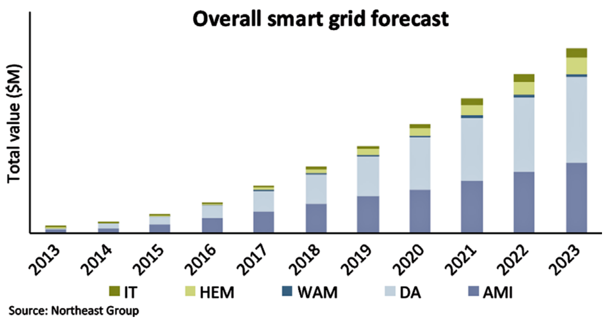


Fig. 8. Combined smart grid forecast in Brazil. By 2013 reach about $50 billion.

in India. Thus, the reliability, quality of supply, efficiency of power and being customer friendly will be improved by introduction of smart grid in India [33].

Power grid of India needs more improvement and proper monitoring to achieve the assumed goal for implementation of smart grid. The energy planning, investment and awareness about smart grid for all Indians are necessary [62].

2.3. Smart grid in Brazil

Brazil is the fifth largest country in the world with population about 199 million people and 404.3 billion kWh electricity consumption in 2007. According to development of Brazil and the electricity demand rate (4.8 percent), the consumption will be around 700 billion kWh by 2020 as shown in Fig. 7 [67].

Brazil will be the next potential smart grid market due to growing economy and investment in city infrastructure [68]. Moreover, $1 billion is invested by Siemens into the smart grid market in Barzil in next five years [69].

Thus, based on Brazil smart grid market forecast from 2012 to 2022 [70], Brazil will become one of the largest smart grid markets in the world by the end of the decade as shown in Fig. 8.

Some researchers worked on implementation and challenges of smart grid in Brazil. Kagan et al. [71] presented a roadmap for the implementation of smart grids in Brazil. In another one, authors [72] stated challenges for smart grid development in Brazil with special attention to smart metering technology and utilization of demand response programs.

For progress monitoring of smart grid in Brazil, using a developed country as an index will be helpful. Suryanarayanan in [67] performed comparative analysis of related infrastructure growth in U.S and Brazil. The authors addressed various modernization efforts for power grid in both countries using smart grid initiative as a template.

Brazil is defined as a leading smart grid market in the region of Latin America [68].

2.4. Smart grid in other developing countries

Utilization of smart grid in other developing countries can be seen in recent years with different approaches [73–76]. Some of them have had a few research works and others have started academic researches with government support and plan [77–82]. This paper describes four countries as a sample: Malaysia, Thailand, Egypt, and Iran as follows:

In Malaysia, as an academic work, Mohamad [77] discussed a proper approach for controlling an islanding operation in smart grid system. The future of smart grid in this country is in a situation based on two major initiatives. (1) CIRED (Congress International des Reseaux Electtriques de Distribution) Malaysia chapter has organized a workshop on smart grid initiatives in the Asia Pacific Region in February 2010 [78]. (2) TNB (electric power utility in Malaysia) has formed a working committee to look into its implementation [78]. Through TNB planning for Smart Grid systems report [79], there are many drivers such as ageing infrastructure, energy, financial and environmental crisis for developing TNB's smart grid. Therefore, TNB has the 25-years Electricity Technology Roadmap (TRM), with a purpose of modernizing electricity supply industry in Malaysia.

On the other hand, Zpryme (research-based advisory firm) prepared are port on Malaysia smart grid market [80]. According to this report, the total technology market of smart grid in Malaysia is designed to increase from $35.2 million in 2011 to $109.0 million by 2016. The rate of power consumption growth in Malaysia is assumed to be 5% per year in next five years and will be doubled in next 20 years. The TNB as a national utility of Malaysia launched the smart grid plan with expected 5000 customers in three different cities. The main purpose of this plan is to reduce carbon emission up to 40 percent of 2005 level. Moreover, integration level of renewable energies is projected to increase to 2080 MW and 4000 MW by 2020 and 2030 respectively.

Finally, as a mega smart grid project in Malaysia, Masers Energy Inc Smart Grid City™ Consortium will develop Melaka, Malaysia as the first fully integrated city with US$ 60 billion investment until 2030. Melaka Carbon Free City with population of 1,000,000 people is a place to show the environmental, financial and operational advantages of smart grid [81].

In Thailand, there is a study about smart grid in Jirapornanan's work. He [82] deployed technology road mapping approach to identify the research and development needed to support the smart grid in Thailand. He focused on infrastructures and concluded that Thailand has lack of some technologies required for smart grid. However, smart grid is considered as a future development by the government and the private sector. Moreover, Araree expressed that there is five fields of lacking technologies according to the roadmap for the smart grid in Thailand. Customer, communication, information, operational and energy technologies are classified as these five sections.

On investment part, US$ 13 billion is provided for utilization of smart grid in Thailand in next 15 years by Provincial Electricity Authority (PEA). Four universities will join the PEA smart meter project. Another two universities are developing a prototype for a Data Cache/Control Unit (DCU.) The proper unit will be used in the advanced metering infrastructure project. This project is expected to be completed by middle of 2013. The PEA will install the pilot system in high-consuming tourist destinations, including Phuket, Chiang Mai and Pattaya [83].

Iran and Egypt are in the group of other developing world, which the study of smart grid is still at academic level.

For Iran, Ashraf-Hesari [74] provided a consensus view on the current status of smart grid technologies and benefits of applying it in Iran. From another aspect, authors in [76] presented the utilization of smart transmission grid in Iran, Khorasan state. As a supplementary, Majid Biabani et al. [75] discussed about driving factors, evolution, challenges and possible solutions of smart grid in Iran. They proved that collaboration among utilities, governments, industries and academic parts would be essential in the design and implementation of Smart Grid in Iran.

Research and practical works about smart grid in Iran is defined as a duty of Iran Energy Efficiency Organization (SABA) under ministry of energy in recent years. However, there is not any proper support from government and only some pilot projects are planned [84].

Egypt, as one of the developing countries, was evaluated as the study case in Walid El-Khattam's paper [73]. Walid aimed to proposes steps to implement smart grid concepts in promoting and integrating RE into electricity grids in general and for the Egyptian grid in particular as an example of developing countries.

3. Conclusion

This review article illustrates that although research about smart grid utilization in developed nations has been started many years ago, however there have been some proper efforts in developing countries in this field. By reviewing and analyzing many articles and governmental documents, it is concluded that China, India and Brazil are frontier of this technology in developing nations. The proposed pattern for smart grid development is prepared as follows:

- **Understanding the need for smart grid:** The main important issue which is discussed about China, India and Brazil shows that although they are in category of developing nations, but they understand the importance of smart grid implementation for their future as proper as developed countries.
- **Governmental support and investment:** Investment for smart grid research and utilization has been defined as a first huge step by China and Brazil. These two countries have had suitable governmental support for grid development.
- **Implementation of pilot projects:** Although India has not been as good as China in investment of research and implementation of smart grid, but the number of research works and investment for pilot projects has made India as pioneer for smart grid in developing countries.
- **Integration with renewable energies:** The future of power grid is associated with renewable energies. Number of research articles and application of renewable energies are assumed necessary before and in parallel with study of smart grid.
- **Start a huge change:** Utilization of smart grid needs a huge change in infrastructure of available power grid. It seems that based on this review, China understands properly this issue.

Therefore, by applying these steps of proposed outcome, the future of all developing nations could be promising. Thailand, Malaysia, Iran and Egypt have been some of developing countries which are investigated further as a sample. These countries have tried to push their nations toward the modernization of power grid.

References

[1] Peng L, Yan G-S. Clean energy grid-connected technology based on smart grid. Energy Procedia 2011;12:213–8.
[2] Abayateye Julius, Anku N, Oguah Samuel. Smart grid: an assessment of opportunities and challenges in its deployment in the Ghana power system. Innovative Smart Grid Technologies (ISGT) 2013.
[3] Mohsen Fadaee Nejad AS, Hashim Hizam, Mohd Amran Mohd Radzi, Mohd Zainal Abidin Ab Kadir. Application of smart power grid in developing countries. In: Proceedings of the IEEE 7th international power engineering and optimization conference. 2013.
[4] Hui Hou JZ, Yongchuan Zhang, Xiongkai He. A brief analysis on differences of risk assessment between smart grid and traditional power grid. In: Proceedings of the fourth international symposium on knowledge acquisition and modeling (KAM) 2011.
[5] Alvial-Palavicino C, Garrido-Echeverría N, Jiménez-Estévez G, Reyes L, Palma-Behnke R. A methodology for community engagement in the introduction of renewable based smart microgrid. Energy for Sustainable Development 2011;15:314–23.
[6] Verbong GPJ, Beemsterboer S, Sengers F. Smart grids or smart users? Involving users in developing a low carbon electricity economy Energy Policy 2013;52: 117–25.
[7] Agrell PJ, Bogetoft P, Mikkers M. Smart-grid investments, regulation and organization. Energy Policy. 2013;52:656–66.
[8] Gao J, Xiao Y, Liu J, Liang W, Chen CLP. A survey of communication/networking in smart grids. Future Generation Computer Systems 2012;28:391–404.
[9] Mah DN-Y, van der Vleuten JM, Hills P, Tao J. Consumer perceptions of smart grid development: results of a Hong Kong survey and policy implications. Energy Policy 2012.
[10] Alonso M, Amaris H, Alvarez-Ortega C. Integration of renewable energy sources in smart grids by means of evolutionary optimization algorithms. Expert Systems with Applications 2012;39:5513–22.
[11] Polo tenti PM, Helmo K. In: Proceedings of IEEE conference on conservative power theory, sequence components and accountability in smart grids. 2010.
[12] Muhammad Mehroze Abdullah BD. Smart demand-side energy management based on cellular technology – a way towards smart grid technologies in Africa and low budget economies. IEEE Africon 2009.
[13] Vehbi C, Gungor DS, Kocak Taskin, Ergut Salih. Smart grid technologies: communication technologies and standards. IEEE Transactions on Industrial Information 2011:7.
[14] Boban Panajotovic MJ, Borislav Odadzic. ICT and smart grid. Telsiks 2011.
[15] Kabalci E, Kabalci Y, Develi I. Modelling and analysis of a power line communication system with QPSK modem for renewable smart grids. International Journal of Electrical Power and Energy Systems 2012;34:19–28.
[16] Network ISGA. The IEA implementing agreement for a co-operative programme on smart grids (ISGAN), 〈http://www.iea-isgan.org〉.
[17] Simões MG. A comparison of smart grid technologies and progresses in Europe and the U.S. IEEE Transactions on Industry Applications 2012:48.
[18] Markovic DS, Zivkovic D, Branovic I, Popovic R, Cvetkovic D. Smart power grid and cloud computing. Renewable and Sustainable Energy Reviews 2013;24: 566–77.
[19] Batista NC, Melício R, Matias JCO, Catalão JPS. Photovoltaic and wind energy systems monitoring and building/home energy management using ZigBee devices within a smart grid. Energy 2013;49:306–15.
[20] Malik AS, Bouzguenda M. Effects of smart grid technologies on capacity and energy savings – a case study of Oman. Energy 2013;54:365–71.
[21] Developing country and emerging economy smart grid perspectives. In: proceedings of IEA smart grid roadmap workshop. 2010.
[22] Fehrenbacher K. 5 reasons why developing countries need smart grids, too. In: Solis N, editor. 〈http://gigaom.com/cleantech/5-reasons-why-developing-countries-need-smart-grids-too/2011〉.
[23] Chebbo M. Electricity networks of the future 2020 and beyond. In: Framework ESG, editor. Proceedings of IEEE general meeting power engineering society. 2007.
[24] Flavia Gangale AM, Onyeji Ijeoma. Consumer engagement: an insight from smart grid projects in Europe. Energy Policy 2013.
[25] China's leading smart grid gathering for interaction and knowledge sharing smart grid china summit Beijin. 2011.
[26] Li MU. GQ. research on intelligent power consumption in smart grid. In: Proceedings of the 2011 international conference on advanced power system automation and protection. 2011.
[27] Sun D-Q. The utilization and development strategies of smart grid and new energy. In: Proceedings of power and energy engineering conference (APPEEC). Asia-Pacific; 2010.
[28] Cunjiang Y, Huaxun Z, Lei Z. Architecture design for smart grid. Energy Procedia 2012;17:1524–8.
[29] Usman A, Shami SH. Evolution of communication technologies for smart grid applications. Renewable and Sustainable Energy Reviews 2013;19:191–9.
[30] Khan RH, Khan JY. A comprehensive review of the application characteristics and traffic requirements of a smart grid communications network. Computer Networks 2013;57:825–45.
[31] Ye Yan YQ, Sharif Hamid, David Tipper A. Survey on smart grid communication infrastructures: motivations, requirements and challenges. IEEE Communications Surveys and Tutorials 2013:15.
[32] Patel A, Júnior JC, Pedersen JM. An intelligent collaborative intrusion detection and prevention system for smart grid environments. Computer Standards and Interfaces 2013.
[33] Acharjee P. Strategy and implementation of smart grids in India. Energy Strategy Reviews 2013;1:193–204.
[34] Hammons TJ. Integrating renewable energy sources into European grids. International Journal of Electrical Power and Energy Systems 2008;30:462–75.
[35] Reddy Depuru LW, Devabhaktuni Vijay, Gudi Kikhil. Smart meters for power grid – challenges, issues, advantages and status. In: Proceedings of power systems conference and exposition (PSCE). 2011.
[36] Depuru SSSR, Wang L, Devabhaktuni V. Smart meters for power grid: challenges, issues, advantages and status. Renewable and Sustainable Energy Reviews 2011;15:2736–42.
[37] Kaufmann S, Künzel K, Loock M. Customer value of smart metering: explorative evidence from a choice-based conjoint study in Switzerland. Energy Policy 2013;53:229–39.
[38] Lin S-Y, Chen J-F. Distributed optimal power flow for smart grid transmission system with renewable energy sources. Energy 2013;56:184–92.
[39] Fadaee M, Radzi MAM. Multi-objective optimization of a stand-alone hybrid renewable energy system by using evolutionary algorithms: a review. Renewable and Sustainable Energy Reviews 2012;16:3364–9.
[40] Fadaee M. Radzi MAM, Ab Kadir MZA, Hashim H. Hybrid renewable energy systems in remote area of equatorial countries. In: Proceedings of IEEE student conference on research and development (SCOReD). 2012.
[41] Alla Mohd EOSchmelter Andreas, Hamsic Nedzad, Morton Danny. In: Proceedings of IEEE conference on challenges in integrating distributed energy storae systems into future smart grid. 2008. p. 1627–32.
[42] Khayyam H, Ranjbarzadeh H, Marano V. Intelligent control of vehicle to grid power. Journal of Power Sources 2012;201:1–9.
[43] Ahn C, Li C-T, Peng H. Optimal decentralized charging control algorithm for electrified vehicles connected to smart grid. Journal of Power Sources 2011;196:10369–79.
[44] Welsch M, Bazilian M, Howells M, Divan D, Elzinga D, Strbac G, et al. Smart and just grids for sub-Saharan Africa: exploring options. Renewable and Sustainable Energy Reviews 2013;20:336–52.

[45] Outlook IWE. Nominal GDP comparison of China, Germany, France, Japan adn USA. 2012.
[46] Bank W. Energy poverty issues and G8 actions. Moscow–Washington DC; 2006.
[47] Thiam D-R. Renewable decentralized in developing countries: appraisal from microgrids project in Senegal. Renewable Energy 2010;35:1615–23.
[48] Saputro N, Akkaya K, Uludag S. A survey of routing protocols for smart grid communications. Computer Networks 2012;56:2742–71.
[49] Elzinga D. Developing a common vision for the grid of the future. In: proceedings of smart grid technology seminar. 2010.
[50] Yi MP T, Sheng-nan S, Hao-ming L, Rahman S. Comparative study on smart grid related R&D in China, the United States and the European Union. Power System Technology 2009;33:15.
[51] (MOST) CMoSaT. In: Proceedings of the China's 12th five-year plan. 2010.
[52] Blumsack S, Fernandez A. Ready or not, here comes the smart grid!. Energy 2012;37:61–8.
[53] GAMMONS HYAB. China Emerges as smart-grid powerhouse. International Business Times; 2012.
[54] Siming Li YC, He Jing, Yongding Hui Hou. Discussion on smart grid development in China. In: Proceedings of power and energy engineering conference (APPEEC). Asia-Pacific; 2011.
[55] Xin-Wei D. Review of smart grid and its development prospect in Sichuan. In: Proceedings of power and energy engineering conference (APPEEC). Asia-Pacific; 2010.
[56] Hammons KPW Tom, Lei Lai Loi. Development in power generation and transmission infrastructures in China. In: Proceedings of IEEE 2007 general meeting. Tampa, FL, USA; 2007. p. 24–8.
[57] Wu Y-N, Chen J, Liu L-R. Construction of China's smart grid information system analysis. Renewable and Sustainable Energy Reviews 2011;15:4236–41.
[58] Chen H, Feng K, Zhang Q, Zhao Z, Zhang L, Li J, et al. Investment evaluation system development based on unified information platform for future smart grid. Energy Procedia 2011;12:10–7.
[59] Sun Q, Ge X, Liu L, Xu X, Zhang Y, Niu R, et al. Review of smart grid comprehensive assessment systems. Energy Procedia 2011;12:219–29.
[60] Hashmi M, Hanninen S, Maki K. Survey of smart grid concepts, architectures, and technological demonstrations worldwide. In: Proceedings of IEEE PES, innovative smart grid technologies (ISGT). 2011.
[61] Lin C-C, Yang C-H, Shyua JZ. A comparison of innovation policy in the smart grid industry across the pacific: China and the USA. Energy Policy, 57; 119–32.
[62] Acharjee JGP. Development prospect of smart grid in India. In: Proceedings of IEEE international conference on power and energy. 2010.
[63] Balijepalli Murthy, Gupta RP, Khaparde SA. Towards Indian smart grids. In: Proceedings of IEEE Conferences. 2009.
[64] Sinha Arup, Neogi SLahiri RN, Chowdhury S. Smart grid initiative for power distribution utility in India. In: Proceedings of IEEE general meeting, power and energy society. 2011.
[65] Acharjee P. Strategy and implementation of smart grid in India. Energy Strategy Reviews 2012.
[66] Ganesh N, Jadhav AAD. Technical challenges for development of smart grid in India. In: Proceedings of IEEE conference. 2012.
[67] Suryanarayanan S. Grid modernization efforts in the USA and Brazil – some common lessons based on the smart grid initiative. In: Proceedings of power and energy society ieee general meeting. 2010.
[68] Fehrenbacher K. Next hot smart grid market: Brazil, ⟨http://gigaom.com/cleantech/the-next-hot-smart-grid-market-brazil/2012⟩.
[69] Siemens acquiring smart grid company in Brazil, ⟨http://www.metering.com/node/212192012⟩.
[70] Brazil smart grid market forecast from 2012 to 2022, ⟨www.northeastJgroup.com2012⟩.
[71] Kagan N. A roadmap for the implementation of smart grids in Brazil. In: Proceedings of the 2012 IEEE PES innovative smart grid technologies (ISGT). 2012.
[72] Rafael Ferreira PL, Valenzuela Paula, Barroso Luiz, Pereira Mario. Regulatory challenges for smart grid developments in Brazil. In: Proceedings of IEEE PES innovative smart grid technologies (ISGT). 2012.
[73] Walid El-Khattan MM, Wahid Hatem. Development of regulatory aspects for promoting smart grid with renewable energy resources. In: Proceedings of IEEE conference on the Egyptian case. 2011.
[74] Ashraf-HesariAH-F A. Smart Grid Applications in Iran. 6thSASTech 2012, Malaysia, Kuala Lumpur. 2012.
[75] Biabani MAG Majid. Smart grid in Iran: driving factors, evolution, challenges and possible solutions. In: Proceedings of IEEE conference. 2011.
[76] Attar TS. Implementations of smart transmission grid in Iran. In: Proceedings of the 20th Iranian conference on electrical engineering, (ICEE2012). 2012.
[77] Mohamad H. An adaptive controller of hydro generators for smart grid application in Malaysia. In: Proceedings of IEEE Conference. 2010.
[78] Malaysia TECo. Renewable energy options and smart grid for green building – an assesment for Malaysia. In: Proceedings of the Green building congress. 2010.
[79] Rakob MY. Planning for smart grid in TNB system. In: Proceedings of IEEE conference on power and energy. 2010.
[80] Zpryme. $109M Malaysian smart grid market by 2016. ⟨http://zpryme.com/news-room/109m-malaysian-smart-grid-market-by-2016-zpryme-reports.html2012⟩.
[81] Benama. Masers energy to invest RM30 bln to set up low carbon project in Malaysia, ⟨http://web6.bernama.com/bernama/v3/news_lite.php?id=6162722011⟩.
[82] Jirapornanan A. Study of smart grid for Thailand and identification of the required research and development. In: Proceedings of IEEE conference. 2010.
[83] Engerati. Thailand smart grid to solve blackout headaches, ⟨http://www.engerati.com/article/thailand-smart-grid-solve-blackout-headaches2012⟩.
[84] SABA. Iran energy efficiency organization, ⟨http://www.saba.org.ir/en/home2013⟩.